

facies of the debris-avalanche deposit. The blast deposit generally contains a larger percentage of juvenile blast dacite than the debris avalanche. In South Coldwater Creek, the matrix facies is readily distinguished from the blast deposits mapped adjacent to the hummocks because the matrix facies contains a high percentage of organic material, soil, prehistorically erupted tephra, and bedrock picked up from surrounding rocks on Johnston Ridge (Fisher and others, 1987).

Blast deposits mapped here can be correlated only with the composite A1 unit of Waitt (1981); this unit includes a layer of pebble gravel with or without sandy finer grained material. Except in the area near Spirit Lake (see Glicken and others, 1989), the blast deposit on top of the debris avalanche cannot be correlated with the units defined by Hoblitt and others (1981), Moore and Sisson (1981), or Fisher and others (1987). The units of the other authors, which were defined on the ridgetops around Mount St. Helens and in South Coldwater Creek, consist of a coarse, friable, fines-depleted lower layer overlain by a layer with more fine ash and parallel to wavy laminations.

#### LAHAR DEPOSITS

On the morphologic map (pl. 3), lahar deposits are shown where they cover most of the surface area of the debris-avalanche deposit and also where they flowed off the west end of the avalanche deposit. Within areas mapped as lahar deposits, there are many isolated hummocks not covered with lahars that could not be shown on the scale of the morphologic map.

On the lithologic map, lahar deposits covering the debris-avalanche deposits are mapped only where they are thick enough (approximately >1 m) to prohibit identification of the lithology of the underlying debris-avalanche deposit. Lahar deposits thinly mantle the debris-avalanche deposit in many other areas. Lahars are also mapped on the lithologic map where they flowed off the west end of the debris-avalanche deposit.

The lahar deposits consist of mudflow, debris flow, and hyperconcentrated lahar-runout deposits (terminology of Pierson and Scott, 1985) that formed from the debris avalanche in the late morning and early afternoon of May 18 (Janda and others, 1981). "Lahar" is the appropriate term here, as it is an inclusive term that describes masses of flowing volcanic debris intimately mixed with water (Fisher and Schmincke, 1984). Voight and others (1981, 1983) and Lipman (1981) referred to the same deposits as "mudflow" units.

The lahar deposits have a generally flat but locally ropy surface morphology (fig. 43). They never form

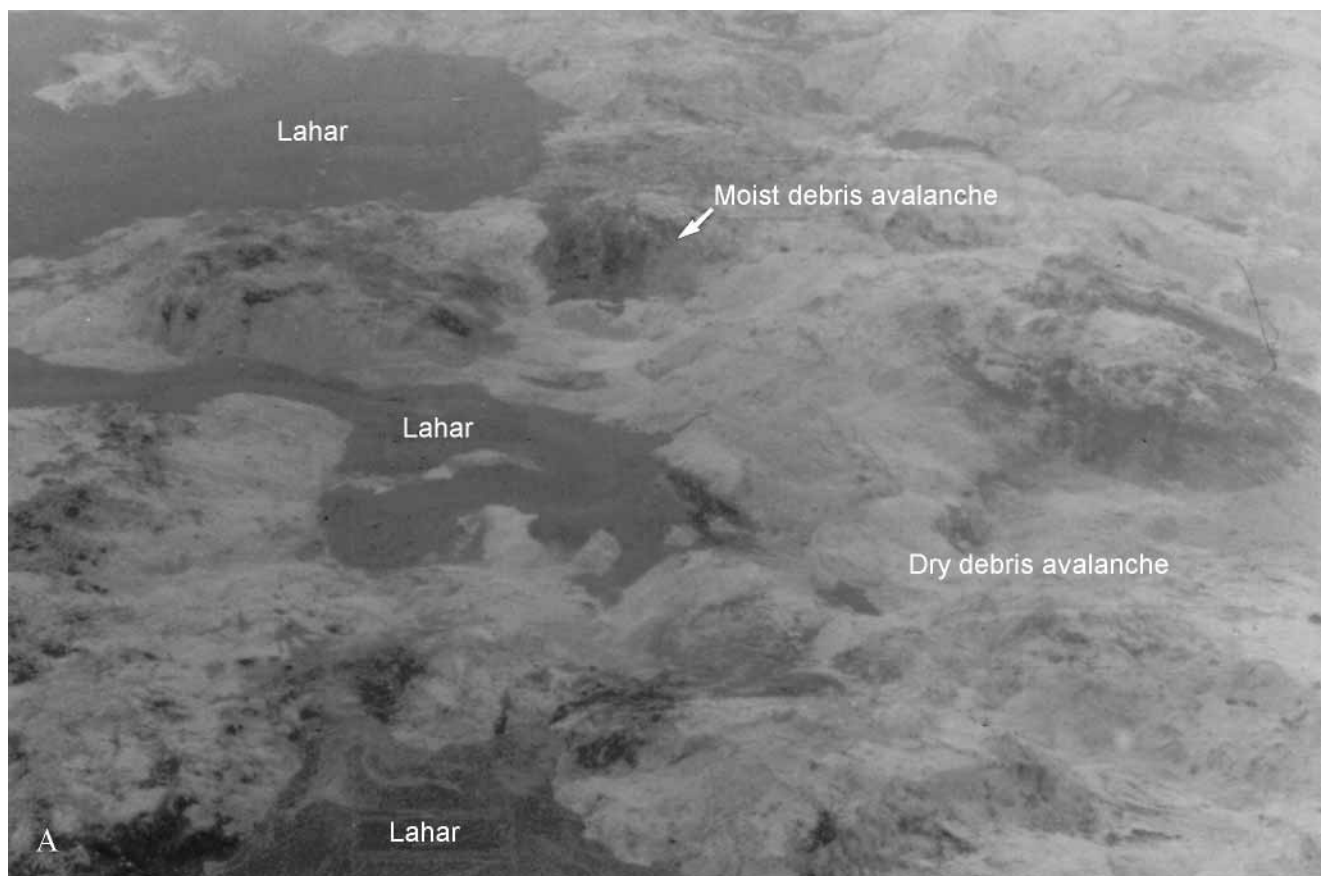
hummocks and, where present, cover the debris-avalanche deposit in the areas between hummocks.

The texture of the lahar deposits is generally distinct from that of the debris-avalanche deposits. They consist of clasts that are as much as tens of centimeters in diameter dispersed in brown finer grained material; they do not contain debris-avalanche blocks transported intact from the old mountain.

During the afternoon of May 18, 1980, while traveling up and down the North Fork Toutle River in a helicopter on a rescue mission, I observed some of the lahars forming from slumping of water-saturated debris avalanche material (fig. 44A). The moving lahars often ponded between hummocks and broke out to form lahars with greater peak discharges. Just after the eruption, some hummocks showed slump features that had clearly generated lahars (fig. 45). Some lahars also formed from headward erosion of channels in the debris avalanche that I saw full of mud on May 18 (fig. 44B). Some formed from incorporation of sediment by stream flows that emanated from springs in the debris-avalanche deposit. The spring that generated the most lahars is at the base of the break-in-slope just west of Maratta Creek (fig. 36). R.P. Hoblitt (oral commun., 1982) observed water to gush from the spring on the afternoon of May 18.

Although the debris avalanche was emplaced shortly after 8:32 a.m. Pacific Daylight Time (P.D.T), the major lahar did not flow off the west end of the avalanche deposit until the afternoon of May 18. I arrived in the North Toutle River valley at 12:18 p.m. and saw the river channel west of the debris-avalanche deposit, but I did not see flowing lahars. The peak stage of lahar generation was at about 1:30 p.m. in the Elk Rock area (Cummins, 1981). Slumping of a significant volume of material and the development of a ground water flow field to form springs apparently required a few hours; also, melting ice may have contributed water to generate lahars, and it probably took a few hours for enough ice to melt (Fairchild, 1985, 1987). Harmonic tremor related to the intense eruptive activity in the afternoon may also have contributed to the generation of lahars (Fairchild, 1985, 1987).

At 12:18 p.m., I saw a coating of mud about 1 cm thick on boulders in the channel just west of the distal end of the debris-avalanche deposit. The coating extended no more than 0.5 m above the surface of the channel; it probably was deposited by muddy Toutle River water pushed in front of the avalanche.



**Figure 44.** Oblique aerial photographs of moving lahars near North Fork Toutle River on afternoon of May 18, 1980. A, Dark-colored moving lahars that formed from slumping of water-saturated hummocks. Light-colored hummocks are dry debris-avalanche deposit. Dark-colored hummocks are moist debris-avalanche deposit showing incipient lahars. Scale uncertain, probably about 150 m wide (*Continued on next page*).

#### **PYROCLASTIC-FLOW DEPOSITS OF THE AFTERNOON OF MAY 18**

Pumiceous pyroclastic-flow deposits rest on top of the debris-avalanche and blast deposits in the area just north of the crater. They cover the debris-avalanche deposit to depths of more than 40 m and have a volume of about  $0.25 \text{ km}^3$  (C.W. Criswell, oral commun., 1984).

The pumiceous pyroclastic-flow deposits are easy to distinguish from the debris-avalanche and the blast deposits. They consist of highly inflated pumice (mostly white to yellow, with some gray fragments) and subordinate lithic debris in glassy, finer grained material. Nearly all the deposits have levees and flow fronts consisting of the coarser grained parts of the deposits (Rowley and others, 1981; Criswell, 1984).

These deposits formed from the continued emptying of the May 18 magma chamber after the initial avalanche and blast events. For the entire morning, the magma produced only a vertical column, but in the afternoon both a

vertical column and pyroclastic-flow deposits were produced (Christiansen and Peterson, 1981; Criswell, 1987).

#### **TERTIARY BEDROCK**

The ridges surrounding the debris-avalanche deposit are composed of well-lithified Tertiary bedrock. These rocks are primarily flows and breccias of basaltic to rhyolitic composition that have been regionally metamorphosed to zeolite or prehnite-pumpellyite facies. Around Spirit Lake, there are some small areas of granitic rocks of the 21- to 22-m.y.-old Spirit Lake pluton (Evarts and others, 1987). The volcanic rocks were correlated with the Oligocene-Miocene Ohanapecosh Formation, which was dated at 31-45 m.y. outside the map area (Hammond, 1980).

Recent work by Evarts and others (1987) casts doubt upon this correlation. The bedrock around Mount St. Helens contains only rare exposures of epiclastic volcanic